volt-ampere characteristics on a CRT. In this application [illegible] staircase corresponds to a particular constant value of base current or of gate voltage.

EXHIBIT A

17-8 MODULATION OF A SQUARE WAVE[4]

The variation of a high-frequency-*carrier* characteristic proportional to a lower-frequency signal is called *modulation*. The parameter being modulated may be frequency, amplitude, or pulse width. The VCO system of Fig. 17-9 is an example of a frequency-modulated (FM) square waveform. Equation (17-17) shows that the frequency f is proportional to the modulating-signal magnitude v_m.

Amplitude Modulation (AM)

By multiplying any carrier waveform by a modulating signal v_m an amplitude-modulated signal is obtained because the instantaneous value of the carrier is proportional to v_m. An analog multiplier, such as the transconductance multiplier of Fig. 16-38, is used in this application for a sinusoidal carrier.

If the carrier v_o is a square wave, the multiplication can be performed very simply with a positive-negative controlled-gain amplifier. The configuration of Fig. 17-10 (with the frequency of the modulating voltage v_m much smaller than that of v_o) is a very simple amplitude-modulated system. In Fig. 17-19*a* the modulating signal v_m is shown as a piecewise linear signal (for ease of drawing), and the carrier is the square wave v_o in Fig. 17-19*b*. The amplitude-modulated wave is sketched in Fig. 17-19*c*. Note that, when $-v_o$ is positive, $v' = v_m$ and when $-v_o$ is negative, $v' = -v_m$. In other words, the square wave is multiplied by the modulating signal. This system is often referred to as a *pulse-height modulator* or a *pulse-amplitude modulator* (PAM).

A Chopper Modulator[10]

A very simple amplitude modulator is obtained by "chopping" the signal with a switch which is controlled synchronously by the square wave. In Fig. 17-20 the switch S_1 is controlled by the negative of the square waveform in Fig. 17-19*b*. An excellent implementation for S_1 is the JFET switch S of Fig. 17-16 or the CMOS analog switch of Fig. 8-28. During T_2 when v_o (in Figs. 17-19 and 17-20) is negative, S_1 is open and $v = v_m$. During T_1 when v_o is positive, S_1 is closed, and $v = 0$, assuming that the closed resistance of S_1 is much smaller than R. For the modulating signal v_m and the chopping signal v_o in Fig. 17-19*a* and *b*, respectively, the waveform v is as indicated in Fig. 17-20*b*. Observe that the waveform v is a *chopped* or *sampled* version of the waveform v_m. It is for this reason that the circuit of Fig. 17-20*a* is called a *chopper*.

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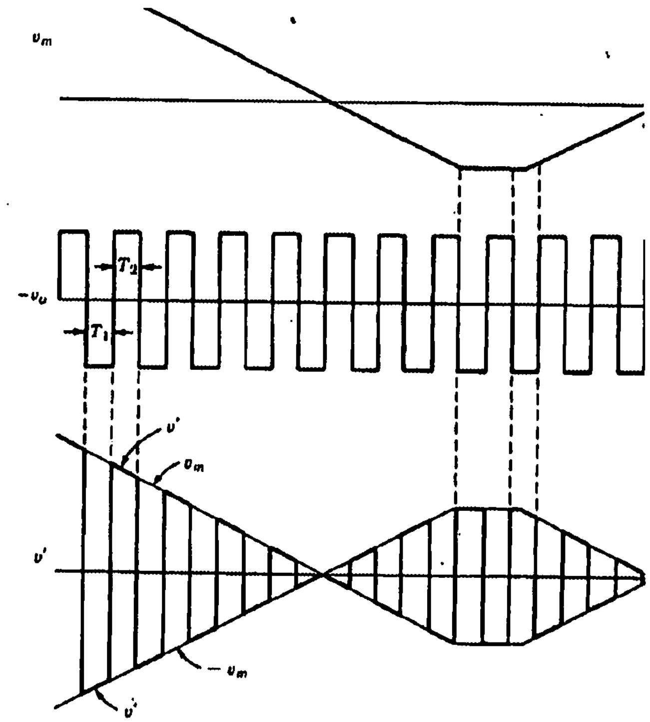


Figure 17-19 (*a*) A modulating signal. (*b*) A constant-frequency squ[…] amplitude modulated waveform.

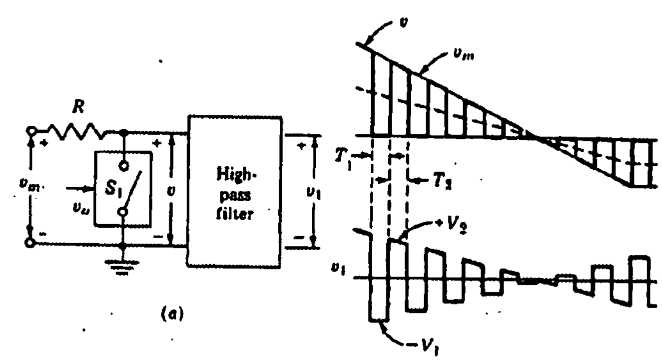


Figure 17-20 (*a*) A chopper modulator. (*b*) A chopped reproduction of […] Fig. 17-19*a*. (*c*) The amplitude-modulated waveform. *Note*: See Fig. 17-19[…]

ENMDI'(D)

MODERATION. Slowing down of a particle by collisions with nuclei. This term is applied especially to neutrons. (See **Nuclear Reactor.**)

MODERATOR. A substance, such as graphite, used to slow down neutrons by means of collisions. Moderators play an important part in nuclear reactors.

MODE TRANSDUCER. A device for transforming an electromagnetic wave from one mode of propagation to another.

MODIFIER. In computer terminology, a quantity used to alter the normal interpretation and execution of an instruction; e.g., an index tag or indirect address tag.

MODULATED AMPLIFIER. An amplifier stage in a transmitter in which the modulating signal is introduced and modulates the carrier.

MODULATED WAVE. A wave, some characteristic of which varies in accordance with the value of a modulating wave.

MODULATING WAVE. A wave which causes a variation of some characteristic of the carrier.

MODULATION. The process or result of the process whereby some characteristic of one wave is varied in accordance with another wave. In radio communications, the modulated wave is called the carrier, and the other wave is called the modulating wave. By extension, the term modulation is applied to any process that varies a characteristic of the carrier. The carrier may be altered in accordance with the intelligence (speech, music, television picture signal, etc.) in three fundamental ways, by varying the amplitude of the carrier giving amplitude modulation, by varying the frequency of the carrier giving frequency modulation, or by varying the phase of the carrier, thereby producing phase modulation.

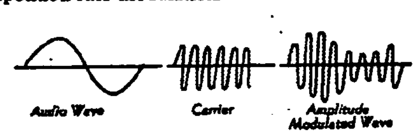
Specific types of amplitude modulation are *absorption modulation*, in which amplitude modulation of the output of a radio transmitter is produced by means of a variable impedance device inserted in or coupled to the output circuit; *controlled carrier modulation*, in which the amplitude of the carrier is made to vary in accordance with the amplitude of the modulating signal (averaged over a short period of time); *cathode modulation*, which is accomplished by applying the modulating voltage to the cathode circuit; and *constant-current* or *Heising modulation*, in which the output circuits of the signal amplifier and the carrier-wave generator or amplifier are directly and conductively coupled by means of a common inductor, which has ideally infinite impedance to the signal frequencies and which, therefore, maintains the common power-supply current of the two devices constant. The signal-frequency voltage, thus appearing across the common inductor, appears also as modulation of the power-supply to the carrier generator or amplifier, with corresponding modulation of the carrier output.

Reference to the accompanying figure will indicate the principal characteristics of an amplitude-modulated wave. The amplitude of the carrier wave is caused to vary in accordance with the audio-frequency wave, i.e., the envelope of the carrier is identical with the audio wave. While the figure shows the carrier modulated with a single tone, the usual case involves a very complex sound wave, but even here the envelope is the same as the sound wave. Such a modulated wave may be analyzed and is found to be really several constant amplitude waves of different frequency. These frequencies are the original carrier and the original carrier frequency plus and minus every audio frequency. Thus for ordinary speech which is a continuous band of frequencies the modulated wave will consist of a band of frequencies from the carrier plus the highest audio to the carrier minus the highest audio. These extra, or side, frequencies constitute the sidebands. This is the reason a definite channel width is required to transmit a modulated signal and why the receiver must pass a band of frequencies in order to reproduce the original sound. The degree of modulation is known as the modulation factor and for amplitude modulation is the increase (or decrease) of amplitude under modulation divided by the original amplitude. It is thus limited to 1 or 100 percent, since the wave cannot be reduced below zero.

In *angle modulation*, the angle of the carrier is the characteristic subject to variation. Therefore, both frequency modulation and phase modulation are forms of angle modulation. In depart from the carrier angle by an amount proportional to the instantaneous value of the modulating wave.

In single sideband modulation, the spectrum of the modulating wave is translated in frequency by a specified amount either with or without inversion; whereas in *vestigial sideband modulation*, there is transmitted one sideband and a portion of the other sideband which lies adjacent to the carrier frequency. This is the modulation system employed by the video portion of television transmitters, as a bandwidth-conservation measure. *Positive modulation* is also used in amplitude-modulated television systems, and is that form of modulation in which an increase in brightness corresponds to an increase in transmitted power. *Negative modulation*, on the other hand, is that form of modulation in which an increase in brightness corresponds to a decrease in transmitted power, while *negative picture modulation* is a method of transmitting the television video signal so that all the picture values are reversed. The brightest portions of the image are represented by the least amount of voltage, while the dark sections of the image have large voltage (or current) values.

Pulse modulation may be (1) modulation of a carrier by a pulse train. In this sense, the term is used to describe the process of generating carrier-frequency pulses. (2) Modulation of one or more characteristics of a pulse carrier. In this sense, the term is used to describe methods of transmitting information on a pulse carrier. There are a number of forms of pulse modulation. In *pulse amplitude modulation*, the modulating wave is caused to amplitude-modulate a pulse carrier. In *pulse-time modulation*, the values of instantaneous samples of the modulating wave are caused to modulate the time of occurrence of some characteristic of a pulse carrier. *Pulse-duration modulation* is pulse-time modulation in which the value of each instantaneous sample of the modulating wave is caused to modulate the duration of a pulse. The terms "pulse-width modulation" and "pulse-length modulation" also have been used to designate this system of modulation. In *pulse-duration modulation*, the modulating wave may vary the time of occurrence of the leading edge, the trailing edge, or both edges of the pulse. *Pulse-position modulation* is pulse-time modulation in which the value of each instantaneous sample of a modulating wave is caused to modulate the position in time of a pulse. Pulse frequency modulation is pulse time modulation in which the pulse repetition rate is the characteristic varied. A more precise term for "pulse frequency modulation" would be "pulse repetition-rate modulation."



Amplitude modulated waves.

Methods of modulation may also be designated by the part of the system to which the modulating voltage or signal is applied, or the means by which it is effected, as in the case of cathode modulation defined earlier in this article. Such methods include *grid modulation, plate (anode) modulation, screen-grid modulation, suppressor grid modulation, reactance modulation, spark gap modulation, and self-pulse modulation.*

MODULATOR. A device to effect the process of modulation. (See **Balanced Modulator; Frequency Modulator; Product Modulator; Pulse Modulator; Reactance Modulator; Rectifier Modulator; Square Law Modulator.**)

MODULE. 1. A self-contained unit of a rocket launch vehicle or spacecraft which serves as a building block for the overall structure. The module is usually designated by its primary function as command module, lunar landing module, etc. 2. A one-package assembly of functionally associated electronic parts, usually a plug-in unit, so arranged as to function as a system or subsystem; a black box. 3. The size of some one part of a rocket or other structure, as the semidiameter of a rocket's base, taken as a unit of measure for the proportional design and construction of component parts. 4. An incremental block of storage or other building block for expanding the capacity of a computer.

MODULUS. 1. The absolute value of a complex number. It may be interpreted as the length of a vector representing the number in complex space. Thus the modulus of $(a + ib)$ is $(a^2 + b^2)^{1/2}$. 2.